

CLAIMS

1. A flexible unbonded pipe comprising at least one polymer layer and one film layer, said polymer layer being bonded to said film layer.

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2. A flexible pipe according to claim 1 wherein the polymer layer comprises at least 50 % by weight, such as at least 70 % by weight, such as at least 85 % by weight of one or more of the polymers selected from the group consisting of polyolefins, such as polyethylene and poly propylene; polyamide, such as poly amide-imide, polyamide-11 (PA-11) and polyamide-12 (PA-12); polyimide (PI); polyurethanes; polyureas; polyesters; polyacetals; polyethers, such as polyether sulphone (PES); polyoxides; polysulfides, such as polyphenylene sulphide (PPS); polysulphones, such as polyarylsulphone (PAS); polyacrylates; polyethylene terephthalate (PET); polyether-etherketones (PEEK); polyvinyls; polyacrylonitrils; polyetherketoneketone (PEKK); copolymers of the preceding; fluorous polymers such as polyvinylidene difluoride (PVDF), homopolymers and copolymers of vinylidene fluoride ("VF2 "), homopolymers and copolymers of trifluoroethylene ("VF3 "), copolymers and terpolymers comprising two or more different members selected from the group consisting of VF2, VF3, chlorotrifluoroethylene, tetrafluoroethylene, hexafluoropropene, and hexafluoroethylene.

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3. A flexible pipe according to claim 1 wherein the polymer layer is cross-linked polyethylene (XLPE).

4. A flexible pipe according to any one of the claims 1 and 2 wherein the film layer is selected from materials of the group consisting of polymer, metal, metal containing compositions and combinations thereof.

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5. A flexible pipe according to claim 4 wherein the film layer is a polymer film comprising one or more of the polymer material selected from the group consisting of polyolefins, such as polyethylene and poly propylene; polyamide, such as poly amide-imide, polyamide-11 (PA-11), polyamide-12 (PA-12 and polyamide-6 (PA-6)); polyimide (PI); polyurethanes; polyureas; polyesters; polyacetals; polyethers, such as polyether sulphone (PES);

polyoxides; polysulfides, such as polyphenylene sulphide (PPS); polysulphones, such as polyarylsulphone (PAS); polyacrylates; polyethylene terephthalate (PET); polyether-ether-ketones (PEEK); polyvinyls; polyacrylonitrils; polyetherketoneketone (PEKK); copolymers of the preceding;
5 fluorous polymers such as polyvinylidene difluoride (PVDF), homopolymers and copolymers of vinylidene fluoride ("VF2 "), homopolymers and copolymers of trifluoroethylene ("VF3 "), copolymers and terpolymers comprising two or more different members selected from the group consisting of VF2, VF3, chlorotrifluoroethylene, tetrafluoroethylene, hexafluoropropene,
10 and hexafluoroethylene.

6. A flexible pipe according to claim 4 wherein the film layer is a metal film preferably selected from the group consisting of aluminum, stainless steel and duplex.

7. A flexible offshore pipe according to claim 4 wherein the film layer is a layered material comprising at least one metal layer, such as two, such as three metal layers, the film layer optionally comprising one or more polymeric layers.

8. A flexible pipe according to claim 4 wherein the film layer comprises metal containing compositions, preferably selected from the group consisting of metal oxides and metal halides.

9. A flexible pipe according to any one of the claims 4-8 wherein the film layer comprises a mixture of polymer with carbon and/or metal and/or metal containing particles.

10. A flexible pipe according to any one of the preceding claims wherein the polymer layer is bonded to the film layer via one or more bondings from the group of chemical bondings and physical bondings.

11. A flexible pipe according to any one of the preceding claims wherein the polymer layer is bonded to the film layer via one or more bondings including at least one of the chemical bondings, ion bondings and covalent bondings.

12. A flexible pipe according to any one of the preceding claims wherein the bonding between the polymer layer and the film layer is stronger than the internal bondings in one of the polymer layer and the film layer.

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13. A flexible pipe according to claim 12 wherein the film layer is a layered material, all interface bondings including bondings between layers of the film and bonding between the polymer layer and the film layer, are stronger than the internal bondings in one of the polymer layer and the film layer.

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14. A flexible pipe according to claims 12 or 13 wherein the interface bonding(s) is/are stronger than the internal bonding of the polymer layer.

15. A flexible pipe according to any one of the preceding claims wherein the interfacial bonding between the polymer layer and the film layer is sufficiently strong to prevent creation of gas pockets between the layers when subjected to an increased carbon dioxides pressure on the film side of the pipe, the increased carbon dioxides pressure e.g. being 1 bar, 5 bars 10, bars or even 50 bars.

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16. A flexible pipe according to any one of the preceding claims wherein the bonding between the polymer layer and the film layer has a peel strength using ASTM D3330 of at least 300 N/m, such as at least 500 N/m, such as at least 700 N/m.

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17. A flexible pipe according to any one of the preceding claims wherein the bonding between the polymer layer and the film layer is stronger than the cohesive forces in one of the polymer layer and the film layer measured by 90 ° peel test.

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18. A flexible pipe according to any one of the preceding claims wherein the surface of the film facing the polymer layer comprises a primer, said primer preferably being selected from the group consisting of a plasma deposited layer, a polymer layer added by spraying gluing and/or pressing.

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19. A flexible pipe according to any one of the preceding claims wherein the polymer layer has a thickness of at least 4 mm, such as at least 6 mm, such as at least 8 mm, such as at least 10 mm, such as at least 12 mm, preferably the polymer layer has a thickness between 4 and 20 mm, such as between 8 and 15 mm.

20. A flexible pipe according to any one of the preceding claims wherein the polymer layer is thicker than the film layer, such as 4 times as thick or more, such as 10 times as thick or more such as 10 times as thick or more, such as 50 times as thick or more, such as up to 100 times as thick.

21. A flexible pipe according to any one of the preceding claims wherein the film layer has a thickness of about 25 μm or more, such as about 100 μm or more, such as about 500 μm or more, such as about 1 mm or less.

22. A flexible pipe according to any one of the preceding claims wherein the film layer provides a fluid permeation barrier against one or more of the fluids methane, hydrogen sulphides, carbon dioxides and water, which is higher, such as least 50 % higher, such as least 100 % higher, such as least 500 % higher, such as least 1000 % higher, than the fluid permeation barrier provided by the polymer layer determined at 50 °C and a pressure difference of 50 bar.

23. A flexible pipe according to claim 22 wherein the film layer provides a fluid permeation barrier against all of the fluids methane, hydrogen sulphides, carbon dioxides and water, which is higher, such as least 50 % higher, such as least 100 % higher, such as least 500 % higher, such as least 1000 % higher, than the fluid permeation barrier provided by the polymer layer determined at 50 °C and a pressure difference of 50 bar.

24. A flexible pipe according to any one of the claims 22 and 23 wherein the film layer is essentially impermeable to one or more of the fluids hydrogen sulphides, methane and carbon dioxide, at a partial pressure for the respective fluids on the first side of the layer of 0.03 bars or more, such as

0.1 bars or more, such as 1 bar or more, such as 10 bars or more measured at about 50 °C and a pressure difference of 50 bar.

25. A flexible pipe according to any one of the claims 22 and 23 wherein the
5 film layer is essentially impermeable to H₂O (preferably liquid or gas), and a pressure difference of 50 bar.

26. A flexible pipe according to any one of the claims 22-25 wherein the film
10 layer is essentially impermeable to hydrogen sulphides at a partial pressure of 0.03 bars or more, such as 0.1 bars or more at a temperature of about 25 °C, preferably at a temperature of about 50 °C, preferably at a temperature of about 90 °C, preferably at a temperature of up to about 150 °C and a pressure difference of 50 bar.

15 27. A flexible pipe according to any one of the claims 22-26 wherein the film layer is essentially impermeable to methane at a partial pressure of 1 bar or more, such as 10 bars or more at a temperature of about 25 °C, preferably at a temperature of about 50 °C, preferably at a temperature of about 90 °C, preferably at a temperature of up to about 150 °C and a pressure difference
20 of 50 bar.

28. A flexible pipe according to any one of the claims 22-27 wherein the film
layer is essentially impermeable to carbon dioxide, at a partial pressure of 1
25 bar or more, such as 10 bars or more at a temperature of about 25 °C, preferably at a temperature of about 50 °C, preferably at a temperature of about 90 °C, preferably at a temperature of up to about 150 °C and a pressure difference of 50 bar.

29. A flexible pipe according to any one of the preceding claims wherein said
30 film layer is the innermost layer of said film layer and said polymer layer.

30. A flexible pipe according to any one of the preceding claims wherein said
film layer is sandwiched between two polymer layers, preferably at least one
of the polymer layers being bonded to the film layer, with a bonding that is
35 stronger than the internal cohesion of said polymer layer.

31. A flexible pipe according to claim 30 wherein the innermost polymer layer of the two polymer layers is selected from the group consisting of polyolefins, such as polyethylene and poly propylene; polyamide, such as poly amide-imide, polyamide-11 (PA-11) and polyamide-12 (PA-12); polyimide (PI); polyurethanes; polyureas; polyesters; polyacetals; polyethers, such as polyether sulphone (PES); polyoxides; polysulfides, such as polyphenylene sulphide (PPS); polysulphones, such as polyarylsulphone (PAS); polyacrylates; polyethylene terephthalate (PET); polyether-ether-ketones (PEEK); polyvinyls; polyacrylonitrils; polyetherketoneketone (PEKK); copolymers of the preceding; fluorous polymers such as polyvinylidene difluoride (PVDF), homopolymers and copolymers of vinylidene fluoride ("VF2 "), homopolymers and copolymers of trifluoroethylene ("VF3 "), copolymers and terpolymers comprising two or more different members selected from the group consisting of VF2, VF3, chlorotrifluoroethylene, tetrafluoroethylene, hexafluoropropene, and hexafluoroethylene.
32. A flexible pipe according to claim 31 wherein the innermost polymer layer of the two polymer layers being PVDF and the polymer layer on the in radial direction outermost of the two polymer layer is cross-linked polyethylene (XLPE).
33. A flexible pipe according to claim 31 wherein the innermost polymer layer of the two polymer layers is cross-linked polyethylene (XLPE).
34. A flexible pipe according to any one of the preceding claims wherein the film is in the form of a tape wound around and optionally bonded to an innermost polymer layer.
35. A flexible pipe according to any one of the preceding claims 1-33 wherein the film is in the form of a tape folded around and optionally bonded to an innermost polymer layer.

36. A flexible pipe according to any one of the preceding claims wherein said film or said film with a primer comprises C atoms, the polymer preferably being a cross-linked polymer with bondings linking to the C atoms of the film.

5 37. A flexible pipe according to any one of the preceding claims wherein said pipe comprises one or more innermost unbonded armouring layers (carcass).

38. A flexible pipe according to any one of the preceding claims wherein said pipe comprises one or more unbonded armouring layers (outer armouring
10 layers) on the outer side of the polymer layer bonded to said film layer, preferably an outer cover layer being placed around said outer armouring layers.

39. A method of producing a flexible unbonded pipe as defined in any one of
15 the claims 1-38, said method comprising the steps of providing at least one polymer layer and at least one film layer and bonding said layers to each other.

40. A method according to claim 39 said method comprising the steps of
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-providing an innermost polymer layer, preferably around a mandrel or an inner armour layer (carcass), more preferably by extrusion, winding or wrapping,

25 -providing a film layer around said innermost polymer layer, preferably by extrusion, winding or wrapping,

-providing a second polymer layer around said film layer, preferably by extrusion, and

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-providing a bonding between at least one of said polymer layers and said film layer, said bonding preferably being provided by subjecting said at least one polymer layer to cross-linking.

35 41. A method according to claim 39 said method comprising the steps of

-providing a film layer around a mandrel or an inner armour layer (carcass), preferably by extrusion, winding or wrapping,

5 -providing a polymer layer around said film layer, preferably by extrusion, and

-providing a bonding between said polymer layers and the film, said bonding preferably being provided by cross-linking of the polymer layer.

10 42. A method according to claim 39 said method comprising the steps of

- providing the innermost layered section of the flexible pipe comprising at least an innermost polymer layer and an armour layer on the outer side of said innermost polymer layer,

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-providing a film layer around said innermost layered section of the flexible pipe, preferably by extrusion, winding or wrapping,

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-providing an outer polymer layer around said film layer, preferably by extrusion, and

-providing a bonding between at least one of said polymer layers and the film, said bonding preferably being provided by subjecting said polymer layer to cross-linking.

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43. A method according to any one of the claims 39-42 wherein the film is treated by corona or by application of a primer for increasing bonding, said primer preferably being applied using CVD, spraying, dipping and/or rolling.

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44. A method according to any one of the claims 39-43 wherein the film or a primer coated onto said film comprises C atoms.

45. A method according to any one of the claims 39-44 wherein at least one polymer layer is cross-linked after being applied in contact with the film.

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46. A method according to any one of the claims 39-45 wherein the film is or comprises a metal tape with a primer, the primer preferably being selected from the group of latex primers, epoxy primers and acrylat/methacrylat primers.